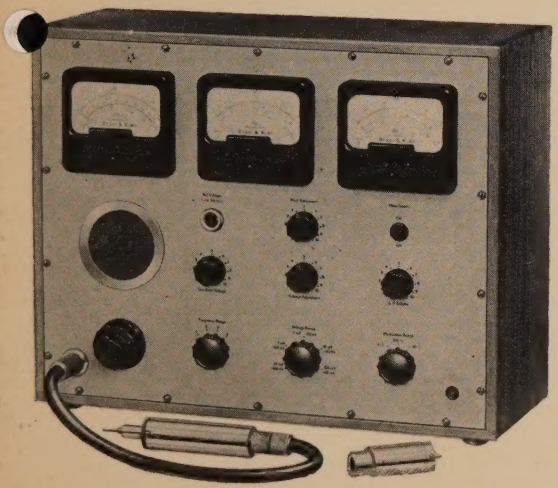
2002

INSTRUCTIONS AND APPLICATIONS

Heterodyne Voltmeter Type 2002



This is a highly sensitive selective tube voltmeter for the measurement of a. c. voltages in the high frequency range and will find a wide application in radio and telecommunication laboratories.

- Beat frequency oscillators
- Low frequency oscillators
- Deviation test bridges
- Strain gauge apparatus
- Frequency measuring bridges
- Distortion measuring bridges
- Heterodyne voltmeters
- Audio frequency spectrometers
- Frequency analyzers
- Level recorders, a. c. and d. c.
- Automatic frequency response recorders
- Automatic A. F. spectographs
- Logarithmic potentiometers
- Noise level potentiometers
- Recording paper
- Polar diagram recorders
- Vacuum tube voltmeters
- Wide range vacuum tube voltmeters
- Diode voltmeters
- D. C. voltmeters
- Megohmmeters
- Microphone amplifiers
- Impact sound generators
- Acoustic standing wave apparatus
- Artificial ears
- Condenser microphones
- Microphone calibration apparatus
- Vibration pick-ups
- Integration networks
- Rotary selectors
- Universal selectors
- Frequency response tracers
- Conductivity meters
- Electronic counters
- Counting rate meters
- Impulse generators
- Portable dose rate meters
- Portable counting rate meters
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HETERODYNE VOLTMETER
TYPE 2002

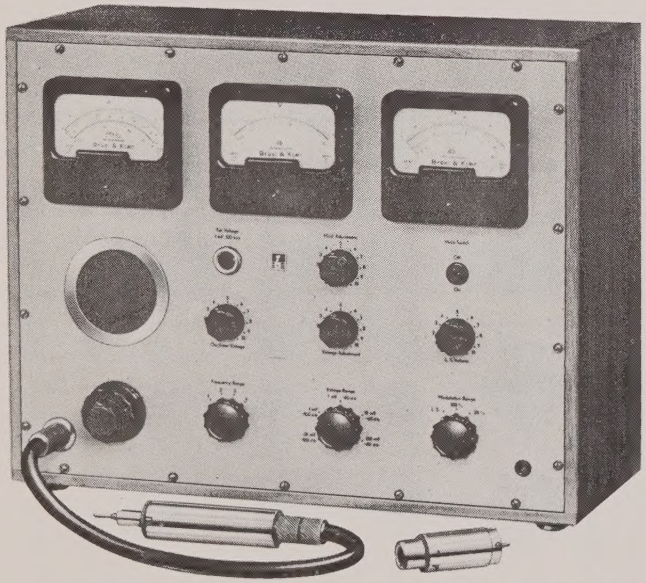


Fig. 1.

The Heterodyne Voltmeter Type 2002 is a selective voltmeter for measuring a.c.voltages in the frequency range 20 kc/s - 30 Mc/s. The voltmeter has full scale deflection for 10 - 100 - 1000 μV and 10 - 100 mV.

The voltage to be measured is applied to the grid of a miniature cathode follower tube placed in a metal box and connected to the voltmeter by a screened jack.

Frequency	Voltage		Modulation	
Loud speaker	Ref. Voltage	Mod. Adjustment	Main Switch	Fuse
	Oscillator Vol.	Vol. Adjustment	LS Volume	
Main Dial	Frequency Range	Voltage Range	Modulation Range	

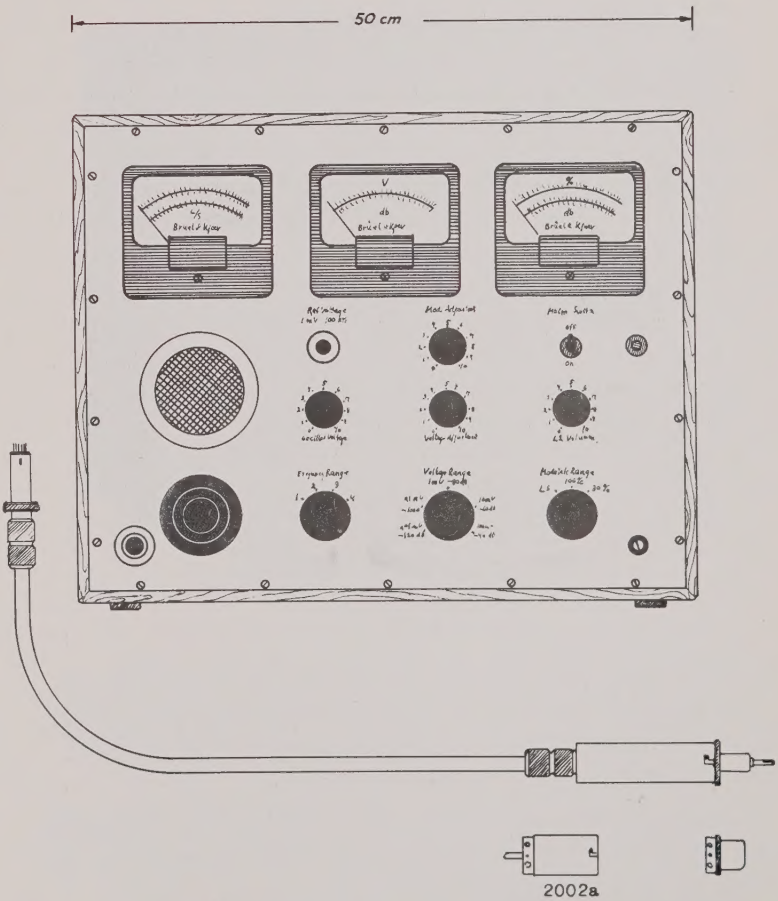


Fig.2. View of front plate with indication table.

The box can be placed in the immediate vicinity of the voltage source, whereby it is possible to use short connecting wires and omit reflection errors. The box can be equipped with connecting terminals fitting 14 mm screened jacks and plugs. (The USA model will also fit jacks according to PL - 259). The input capacity is (without connecting terminals) about 12 μμF and the leakage resistance is at lower frequencies about 5 MΩ. If the voltage to be measured comprises a d.c.component a suitable blocking condenser should be used.

The voltage range may be extended additionally by means of the Capacitive Attenuator Type 2002a, which decreases the voltage 40 db, so that the full range is extended to 10 V. The input capacity is reduced to about 2 μμF and the leakage resistance (at the lower frequencies) is increased to several thousand MΩ. The Capacitive Attenuator will furthermore block out d.c.components of the input voltage.

The a.c.voltage from the cathode-follower is led to the converter stage, using the hexode section of a triode-hexode tube as a mixer and the triode section as the local oscillator. The oscillator can be tuned continuously through 4 ranges. Corresponding input frequencies are 20 - 2000 kc/s, 2 - 6, 6 - 12 and 12 - 27 Mc/s, the oscillator frequency being equal to the sum of the input frequency and the intermediate frequency of 1650 kc/s. The input frequency can be read from the instrument's scale with an accuracy of ± 2 % and ± 2 kc/s.

As the input circuit is not tuned, the instrument will also respond to an oscillator frequency which is equal to the difference between the input frequency and the intermediate frequency. This is, however, true only for input frequencies higher than 3300 kc/s (twice the IF), since it is impossible to tune the oscillator to a frequency lower than 1650 kc/s. Consequently, if the frequency of a signal is higher than 3300 kc/s, the signal should be tuned in with both possible adjustments of the oscillator. The higher of the two readings on the frequency scale is then the right one.

For the frequency range 27 - 30.3 Mc/s only the lower oscillator

frequency is available. Consequently, when tuning to a frequency in that range, the frequency scale should be set to the desired frequency minus 3.3 Mc/s.

In consequence of the aperiodic input circuit the instrument will give additional responses owing to harmonics of the oscillator frequency and to higher order of mixing products. Though these responses are considerably weaker than the main signal, care must be taken when analyzing an unknown complex voltage.

A constant oscillator voltage is necessary for securing a sensitivity independent of the input frequency. This is achieved by adjusting the triode's anode voltage until the oscillator voltage reading on a grid current moving-coil instrument has a fixed value.

The conversion conductance of the mixer tube will decrease for increasing input frequencies above 5 Mc/s. This is compensated for by mismatching the transmission cable connecting the cathode follower and the mixer tube. In this way the instrument has a flat frequency response characteristic better than $\pm$ 0.5 db up to 27 Mc/s.

The anode circuit of the mixer tube has a band-pass filter tuned to the I.F. and connected to the grid of a cathode follower, the cathode circuit of which comprises a resistive attenuator for changing the sensitivity of the instrument in steps of 20 db.

The voltage from the attenuator is amplified in a 3-stage I.F.-amplifier with 8 tuned circuits and applied to a diode rectifier. In the circuit of the rectifier a moving-coil instrument is inserted calibrated for reading the input voltage. The scale of this instrument is logarithmic in a range of 20 db.

For the sensitivity adjustment the Heterodyne Voltmeter is provided with an oscillator, supplying a stabilized voltage of 1 mV at 100 kc/s to a screened jack in the front plate. When adjusting the sensitivity, this jack is connected to the input terminals, and the amplification is adjusted by means of a variable resistor in the cathode circuit of the first I.F. tube. As the grid of this tube is connected to the low-impedance attenuator no detuning of

any I.F.circuit will occur.

The reference voltage will change by less than 2 % for a 10 % variation in the mains supply voltage. When the mains voltage is at its stated value an overall accuracy of ± o.5 db up to 6 Mc/s and ± 1 db up to 30 Mc/s is to be expected.

However, this accuracy is achieved only for voltages essentially above the Heterodyne Voltmeter's level of inherent noise which is 3 - 4 μV. Input voltages about the noise level can be measured by comparing with a reliable standard signal generator.

Another limitation of the usable measuring range will occur at the lower input frequencies for which the corresponding oscillator frequency approaches the I.F. and tends to block up the I.F.amplifier. Consequently, the higher the frequency is, the lower the level of the measurable input voltage. As indicated on the graph, where the order of magnitude of this effect is shown, this limitation is small in comparison with the frequency range of the instrument.

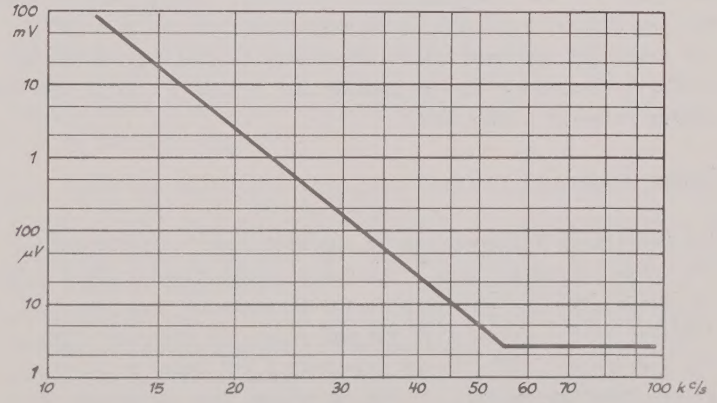


Fig. 3.

In a small range around the I.F., the input signal passing the mixer tube without frequency conversion interferes with the I.F. signal. As the I.F.sensitivity of the instrument is a little higher than the signal frequency sensitivity, the readings will in this range be too high, as is seen from Fig.4.

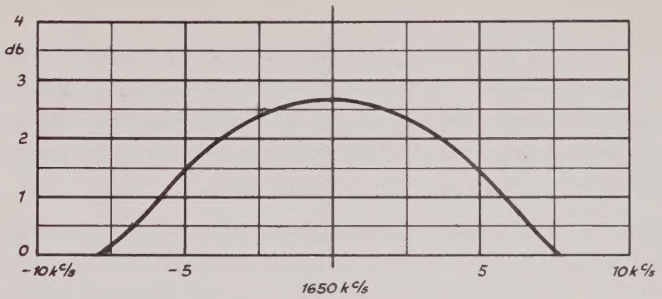


Fig. 4.

The diode rectifier following the I.F.amplifier is connected to an A.F.amplifier driving either a loudspeaker for tuning-in the signal or a copper-oxide rectifier instrument for measuring the degree of modulation. The scale of this instrument has a direct modulation % calibration and is valid when the I.F. voltage on the diode has a fixed value. This is secured by adjustment of the I.F.amplification with a variable resistor, which is inserted instead of the one formerly mentioned, at the same time as the A.F.amplifier is switched from the loudspeaker to the meter. The modulation meter has two ranges, with full scale deflection for 31.6% and 100 %. The frequency response characteristic is essentially determined by the I.F.sideband cut-off and is flat within ± 1 db in the frequency range 30 - 2000 c/s.

Power Supply

The Heterodyne Voltmeter can be operated from a 115-127-150 or 220 volts a.c. power line. The power consumption is about 65 W. The proper line voltage is selected by means of a switch which is operated with a screwdriver through a hole in the rear plate of the instrument. The voltage selected is indicated by a pilot disc ganged with the switch. During switching, the instrument should be disconnected from the power line.

A fuse in the primary circuit of the power transformer is placed in a socket on the front plate.

If it is desired to operate the Heterodyne Voltmeter from a d.c. line or storage battery a vibrator or a rotary converter is required.

The primary circuit of the transformer comprises an R.F.blocking filter. The capacitors of this filter are subject to the line voltage, even when the instrument is switched off by means of the built-in main switch. In order not to load the condensers unnecessarily, the instrument should be disconnected from the power line when not used.

Operation

The instrument is started by means of the main switch and is ready for operation some 40 seconds later. Stable amplification is obtained in about 10 minutes.

The frequency range selector is placed on 2, 3 or 4, the voltage range switch on 100 mV, and the zero setting of the R.F.meter is adjusted with the potentiometer down to the right. Now, the sensitivity is adjusted by using the reference voltage: The input terminals are connected to the screened jack, the voltage selector is set to 1 mV, and the modulation switch to "loudspeaker", and the 100 kc/s reference signal is tuned in. The oscillator voltage is then adjusted to the red mark on the modulation meter, and finally the R.F.adjustment potentiometer is turned to full deflection on the R.F. meter.

When using the Heterodyne Voltmeter, the frequency of the input signal is read from the frequency scales in combination with the frequency range selector. The voltage is read from the R.F.instrument scale in combination with the attenuator dial, when the modulation switch is in the loudspeaker position and the oscillator voltage has been adjusted to the red mark. If the degree of modulation has to be measured, the modulation switch is set to 100 % or the 31.6 % range, and full scale deflection is produced by turning the modulation adjustment potentiometer. This done, the modulation percentage can be read on the modulation meter.

The accuracy of the measurements and some restrictions in the ranges are mentioned above.

Re-Alignment

Re-aligning the circuits of the Heterodyne Voltmeter, for example when tubes have been replaced, is accomplished with the aid of a reliable laboratory standard signal generator. Under special circumstances it may be convenient also to align the sensitivity of the instrument to the signal generator used as a voltage source for the Heterodyne Voltmeter. The instruments are then tuned to 1 Mc/s and the sensitivity of the voltmeter is adjusted to the readings of the generator. After that the input of the Heterodyne Voltmeter is connected to the reference voltage terminal and the instrument is tuned to 100 kc/s. With a screwdriver the reference voltage is now adjusted by means of the upper potentiometer on the rear plate to give a reading of 1 mV.

If the tuned circuits of the Heterodyne Voltmeter are to be re-aligned it will be necessary to remove the instrument from the cabinet by taking out the front plate screws.

A 1650 kc/s signal of o.5 mV is then applied to the input terminals and the instrument is tuned to about 1 Mc/s and set on the 1 mV range. The 8 I.F.circuits are now tuned to maximum deflection of the R.F.instrument. It is also possible to use a sweep-frequency oscilloscope for this alignment.

The iron cores of the I.F. coils are sealed with wax. Before turning them round, which should be done by a screwdriver made of ebonite or similar insulation material, the wax should be removed, or a little heating should be used.

The oscillator circuits are adjustable in a similar manner through holes in the bottom screening. Each tuning range has a trimmer condenser and an inductor with a dust-cure for adjustment. The inductor is adjusted in the low-frequency end of the range, and the trimmer is used at higher frequencies.

Re-adjustment of the modulation ranges is made by turning the lower potentiometer in the rear of the instrument with a screwdriver. This adjustment does not require the removal of the instrument from the cabinet.

Attenuator 2012

When it is wished to extend the voltage range of the Heterodyne Voltmeter Type 2002 above o.1 volt, the Capacitive Attenuator 2012 is used to diminish the input voltage by a factor of 100.

The attenuator contains a small air condenser, adjustable by a screening plunger between the condenser plates. If a re-adjustment should be required, a low-impedance laboratory standard signal generator is necessary. A signal of 1 mV at 1 Mc/s is applied directly to the input terminals of the Heterodyne Voltmeter and full scale deflection is tuned in. 2012 is now inserted, the signal is increased to 100 mV, and the same deflection is produced by turning the plunger with a screwdriver through a small hole in the wall of 2012 .

The plunger is sealed with a cellulose lacquer, and consequently a little solvent material should be used before turning.

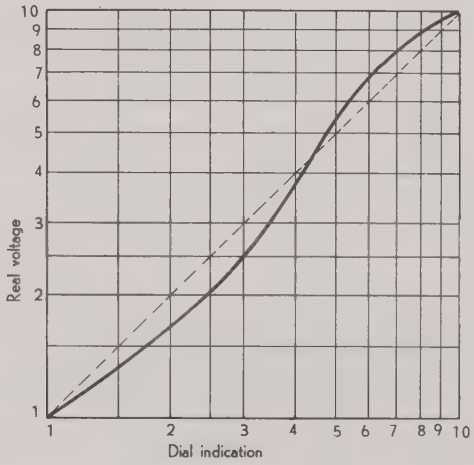
As the mechanical dimensions in the input circuit are changed when 2012 is inserted, the frequency response characterstic is subject to minor alterations in the high-frequency end.

Applications

The Heterodyne Voltmeter is an extremely useful instrument in the radio laboratory, and a few examples to show this will now be given:

Control of Signal Generators

The Heterodyne Voltmeter is a very handy and practical instrument for the checking of frequency, modulation and particularly output voltages of standard signal generators. The frequencies can be checked by the Heterodyne Voltmeter in connection with a frequency standard, for example a crystal-controlled multi-vibrator. The frequency exactness of the Heterodyne Voltmeter is usually not high enough to permit its use as a frequency standard. It is therefore necessary to check fixed points on the frequency scale by means of a crystal-controlled generator. The output voltages for all the attenuator positions of the signal generator can be



Step corrections

Indication	Real value
10	10.8
100	98
1000	1040
10000	9800
100 000	100 000
μV	μV

Frequency 1 Mc/s
Signal Generator

Fig. 5. Correction curve for a laboratory signal generator.

read off, for different frequencies, and in this connection it is a great advantage that the attenuator of the Heterodyne Voltmeter works on a fixed frequency, and therefore gives readings which are quite independent of frequency. If the signal generator's attenuator is not absolutely exact, it is quite easy with the help of the Heterodyne Voltmeter to make an error curve, as for example is shown in fig. 5. Also, the degree of modulation (usually 30%) of the signal generator can be checked and adjusted.

A set-up for measuring the degree of distortion from a signal generator can be seen in fig. 6, both the main carrier frequency and the harmonics being determined, as seen in the figure. Finally, it might be mentioned that the Heterodyne Voltmeter can be used for the checking of alignment oscillators

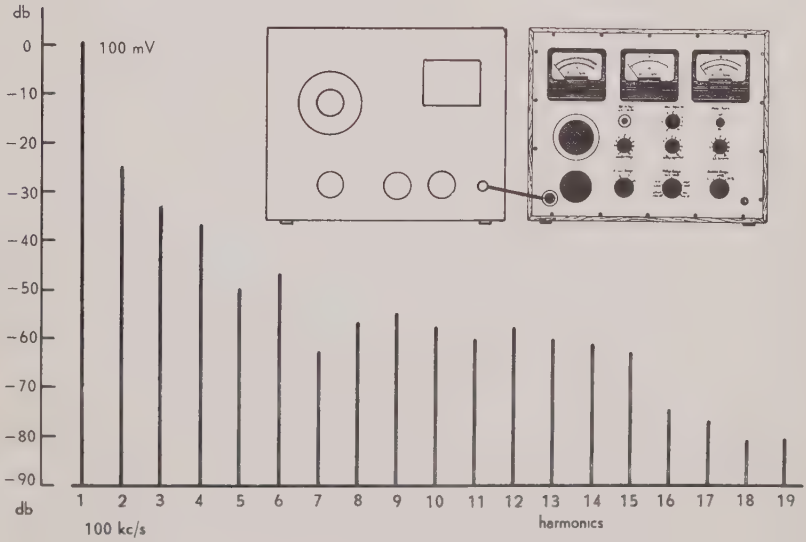


Fig. 6. Measurement of distortion from a signal generator (Laboratory Model MS 11)

as shown for example in fig. 7, where the Heterodyne Voltmeter is

used to record the frequency spectrum of a multi-vibrator, whose many powerful harmonics are used in aligning the oscillator and signal frequency circuits in radio receivers.

Fig. 8 shows a diagram of the potential distribution along a H.F. cable, which connects the central signal generator with the different trimming points in a radio factory. The voltage distribution curve is as a rule dependent on the frequency and should therefore be worked out for all the frequencies which might be of interest. If for example the terminal impedance does not correspond to the characteristic impedance of the cable, standing

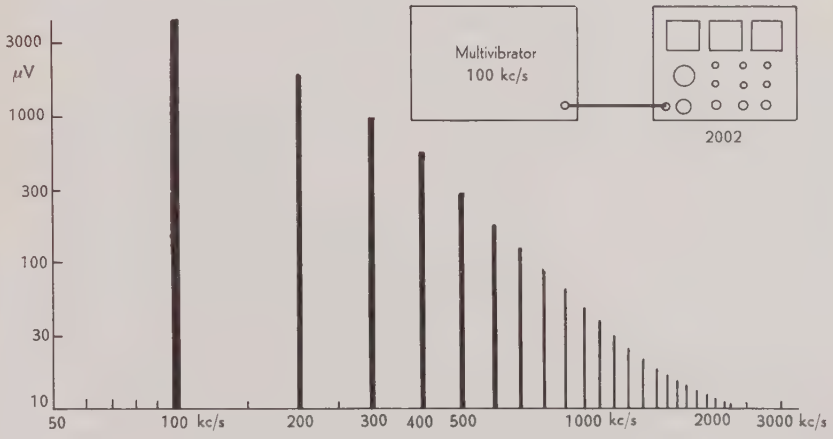


Fig. 7. Spectrum of harmonics from a multi-vibrator.

waves will be obtained, whose amplitude and position can be measured, as shown in the figure. In a similar way the cables in an antenna distribution system can be checked. The antenna amplifier is fed by means of a signal generator, and with the Heterodyne Voltmeter it is possible to measure the voltages at all the receiver connecting-points throughout the whole building, as shown in fig. 9. At the same time, of course, the antenna ampli-

fier's frequency characteristic and gain are checked.

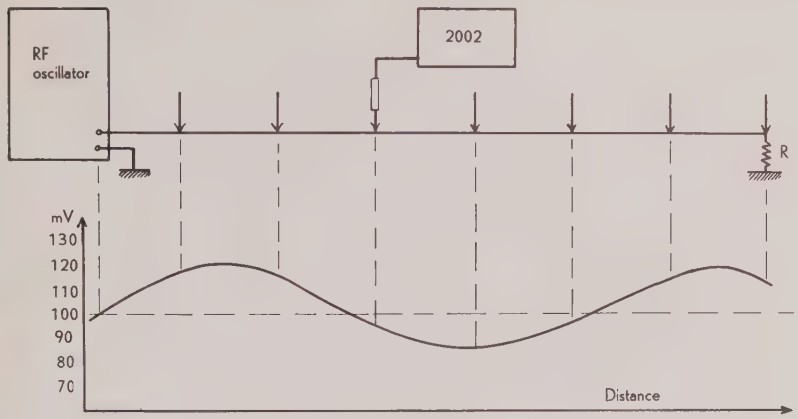


Fig. 8. Checking an R.F. distribution cable in a radio factory.

Amongst the easier measurements can be mentioned the recording of the spectrum of broadcast transmitters and fig. 10 shows the long-wave range measured in the neighbourhood of Copenhagen. Fig. 11 shows the noise spectrum from a rotary converter driven by the mains power supply, and fitted with a noise-filter condenser. The noise is measured as picked up on a nearby antenna. The effective height H_{eff} of an antenna for a particular frequency band can be measured by means of the Heterodyne Voltmeter if one knows the field strength A in mV/m at the point in question, produced by a radio station on the appropriate frequency, and one measures the antenna voltage E in mV relative to earth, on the station's frequency (fig. 12). The antenna effective height H_{eff} can be calculated from the equation

$$E = A \times H_{eff}$$

With a set-up such as shown in fig. 13 it is possible to measure variations in the field strength at a permanent antenna (fading). The antenna is coupled to the Heterodyne Voltmeter and the va-

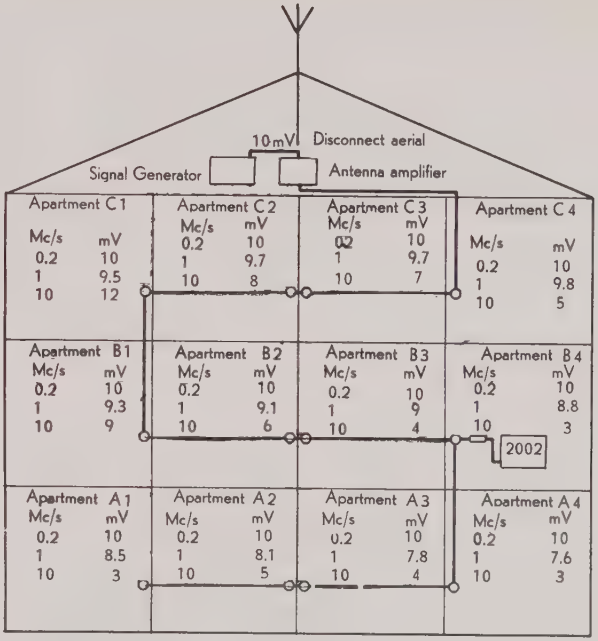


Fig. 9. Checking of voltage distribution and gain for an antenna amplifier with distribution cables.

riations in field strength recorded by means of Level Recorder type 2301, coupled to the Heterodyne Voltmeter's R.F. meter through DC-AC Inverter 4610. The curve shows the antenna voltage from an Italian station in the 41 metre band, measured at Copenhagen. The paper speed was 10 mm/s.

The Heterodyne Voltmeter is extremely useful for more detailed investigations of radio receivers, for example, the measurement of oscillator and I.F. voltages. Fig. 14 shows a sketch of a set-up to measure the radiation from a radio receiver to its antenna. If the coupling between the oscillator and antenna circuits in a superheterodyne receiver is too close, voltages at the oscillator frequency may be present between the antenna termi-

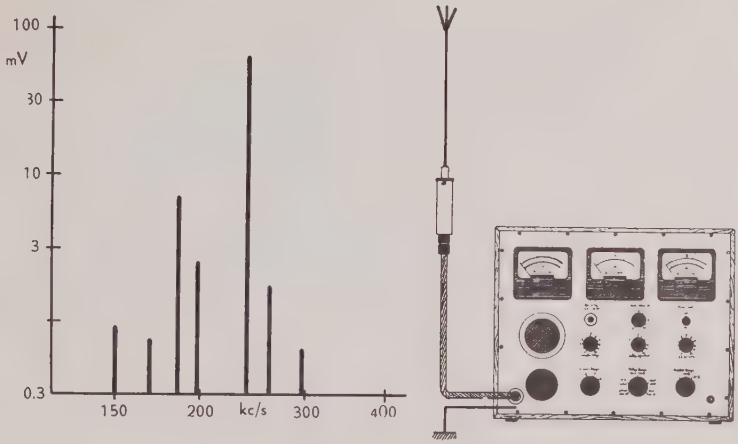


Fig.10. Spectrum of broadcasting stations measured in the vicinity of Copenhagen.

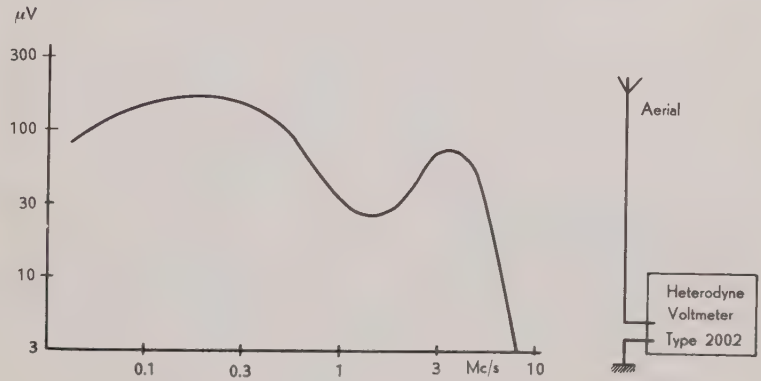


Fig.11. The noise spectrum from a rotary converter measured on a neighbouring aerial.

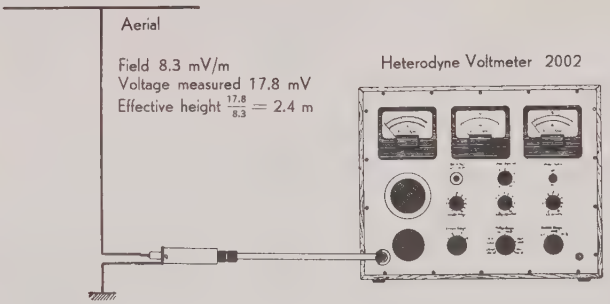


Fig. 12. Determination of the effective height of an aerial.

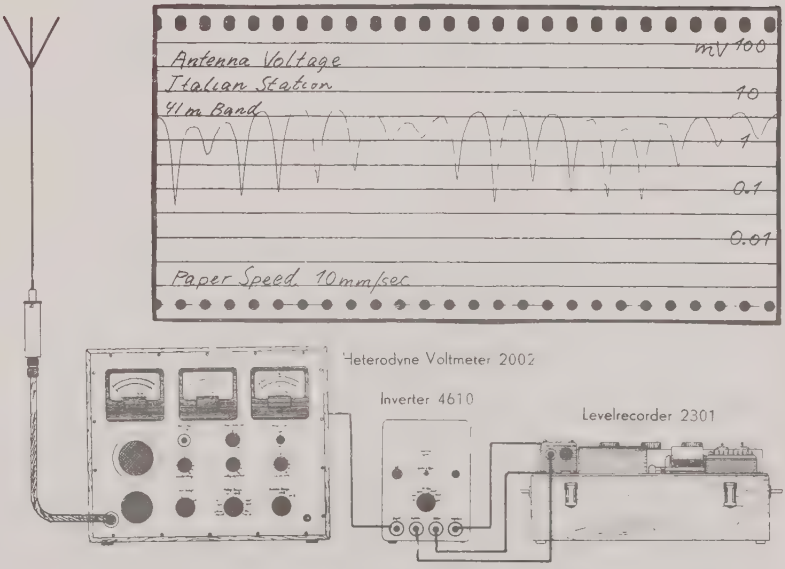


Fig. 13. Recording of field strength variation (fading) with the Heterodyne Voltmeter 2002, the Inverter 4610 and the Level Recorder 2301.

nal and earth, producing radiation from the receiver antenna which can be very disturbing for nearby receivers. This condition is particularly disturbing with common-antenna systems. Because of this, regulations are set down in several countries for the maximum voltage a receiver may be allowed to produce in a standardized dummy antenna. In Norway, for example, the maximum

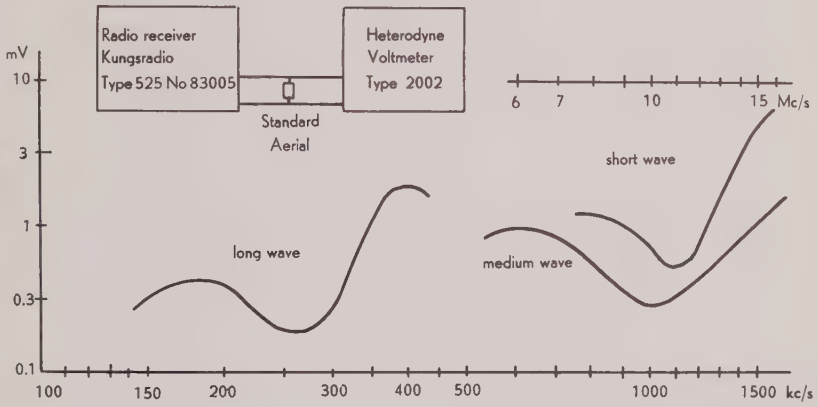


Fig. 14. Oscillator frequency voltages measured on the aerial terminal of a receiver with one stage R.F. amplification (Kungsradio type 5251 No.83005).

is 1 mV for frequencies below 1600 kc/s, and a maximum of 100 mV for higher frequencies. The Heterodyne Voltmeter is particularly well suited for the measurement of such small voltages. Television receivers can also be investigated by means of the Heterodyne Voltmeter, particularly in the circuits after the mixer stage, where an I.F. of between 8 and 30 Mc/s is normally employed.

The Heterodyne Voltmeter can naturally also be used in the investigation of the output from the different stages in radio transmitters, for example the modulator and master oscillator stages.

Measurement of Degree of Modulation

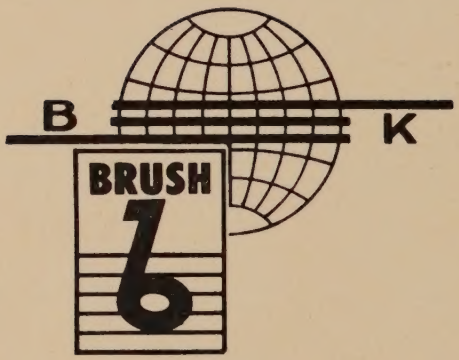
Most laboratory signal generators are constructed with an untuned modulator stage after the oscillator stage, and the modulation usually takes place by leading both the high frequency voltage from the oscillator stage and the low frequency voltage from the built-in modulation generator to the grid of the modulator tube. In this way one makes sure that the low frequency voltage has no appreciable reaction on the oscillator stage, at least not for the medium and low frequencies. However, there will usually be a reaction on the short wave band, the modulation tube's grid exhibiting a somewhat varying capacity with respect to the cathode on account of the low frequency voltage, and this varying capacity will give rise to a frequency modulation of the oscillator voltage. The result will therefore be that on the short wave band the signal generator's output will be both frequency and amplitude modulated. When such a double-modulated signal is fed to a selective amplifier, for example the 2002 I.F. amplifier, one will, when the Heterodyne Voltmeter is adjusted for maximum deflection on the carrier meter, measure about the correct degree of amplitude modulation, as the signal will fall just at the peak of the selectivity curve, so that the frequency modulation will not be particularly noticeable. If, however, the receiver is detuned a little to one side of the signal, the frequency modulated signal will thus fall on one of the selectivity curve's very steep sides, and the frequency modulation will then give rise to a powerful amplitude modulation of the signal from the selective amplifier. This amplitude modulation is in ne case of one of the side-bands in phase with the signal generator's amplitude modulation, and in the case of the other side-band, in antiphase. The result is that the degree of modulation measures considerably more when tuning to one side of the signal than the other, and a completely wrong measuring result is obtained for the degree of modulation if one tunes for maximum deflection on the modulation meter, which would correspond to tuning for maximum on an output meter, with an ordinary receiver. When taking sensitivity measurements on an ordinary receiver with the help of an output meter and signal generator having the fault mentioned, one will therefore also obtain quite in-

correct results, which is an experience well known to most radio laboratories.

It is relatively easy, with the Heterodyne Voltmeter 2002, to find out whether the signal generator has troublesome frequency modulation. If the signal generator is without fault, the maximum deflection on the carrier frequency meter will actually produce simultaneously a maximum deflection on the modulation meter, when the Heterodyne Voltmeter is switched to measuring modulation. If maximum deflection is obtained on the carrier frequency meter, and then by turning a little off-tune it is noted that the deflection on the modulation meter increases with turning to one side and decreases with turning to the other side, one can be fairly certain that the signal generator used is frequency modulated, and that the wrong degree of modulation is being measured. If the loudspeaker is switched on instead of the modulation meter, one can usually also hear a distinct distortion of the signal, as soon as exact tuning for resonance has not been made.

Even expensive signal generators for laboratory use have often some frequency modulation. However, with 2002 one is only first troubled by it when measuring on frequencies which lie above 6-10 Megacycles. The small cheap service oscillators used in radio service stations are usually very bad. In radio transmitters no frequency modulation is normally allowed, and so one has normally no trouble when measuring the degree of modulation on such transmitters with the Heterodyne Voltmeter.

As the degree of modulation is measured with type 2002 at a constant frequency of the H.F. signal, namely the Intermediate Frequency, it follows that the precision of the modulation measurements is the same for all frequencies.



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